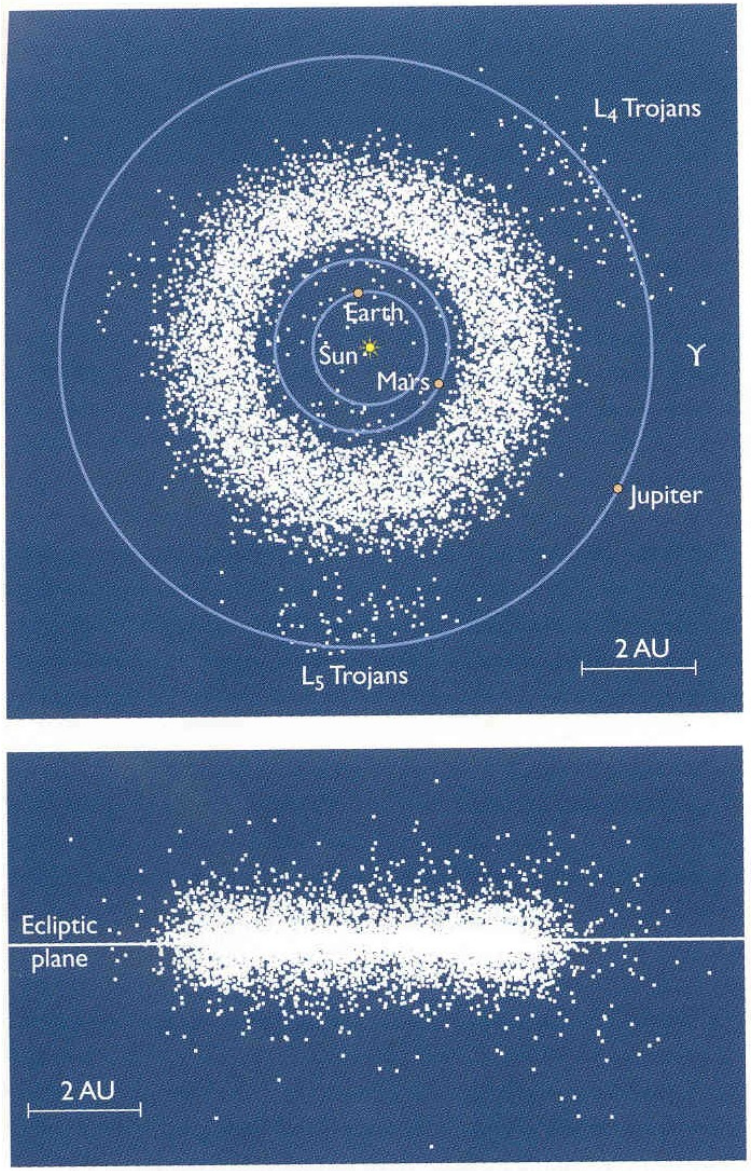
Astr 2310 Thurs. May 5, 2016
Today's Topics

- **Chapter 11: Small bodies in the Solar System**
  - **Asteroid Belt & Meteorites**
    - **Physical Properties**
    - **Composition**
    - **Origin**
  - **Comets**
    - **Physical Properties**
    - **Composition**
    - **Origin**
  - **Kuiper Belt Objects**
    - **Physical Properties**
    - **Composition**
    - **Origin**

Chapter 11: Small Bodies in the Solar System
I. Asteroid Belt

- Most asteroids found between Mars & Jupiter
- Distribution of orbital semi-major axes is non-uniform with distinct gaps (Kirkwood gaps)
  - Orbits in resonance with Jupiter are "cleared out"
- Broadly classified into families by colors and infrared spectroscopy
  - Stoney: silicate absorption features indicate rocky surface
  - Metallic: metalic surface – origin of Nickel-Iron meteorites
  - Vesta: unique – basaltic on one hemisphere, metallic on the other (differentiated and broken-up by massive collision). Volcanic flows in its early history!

Asteroids

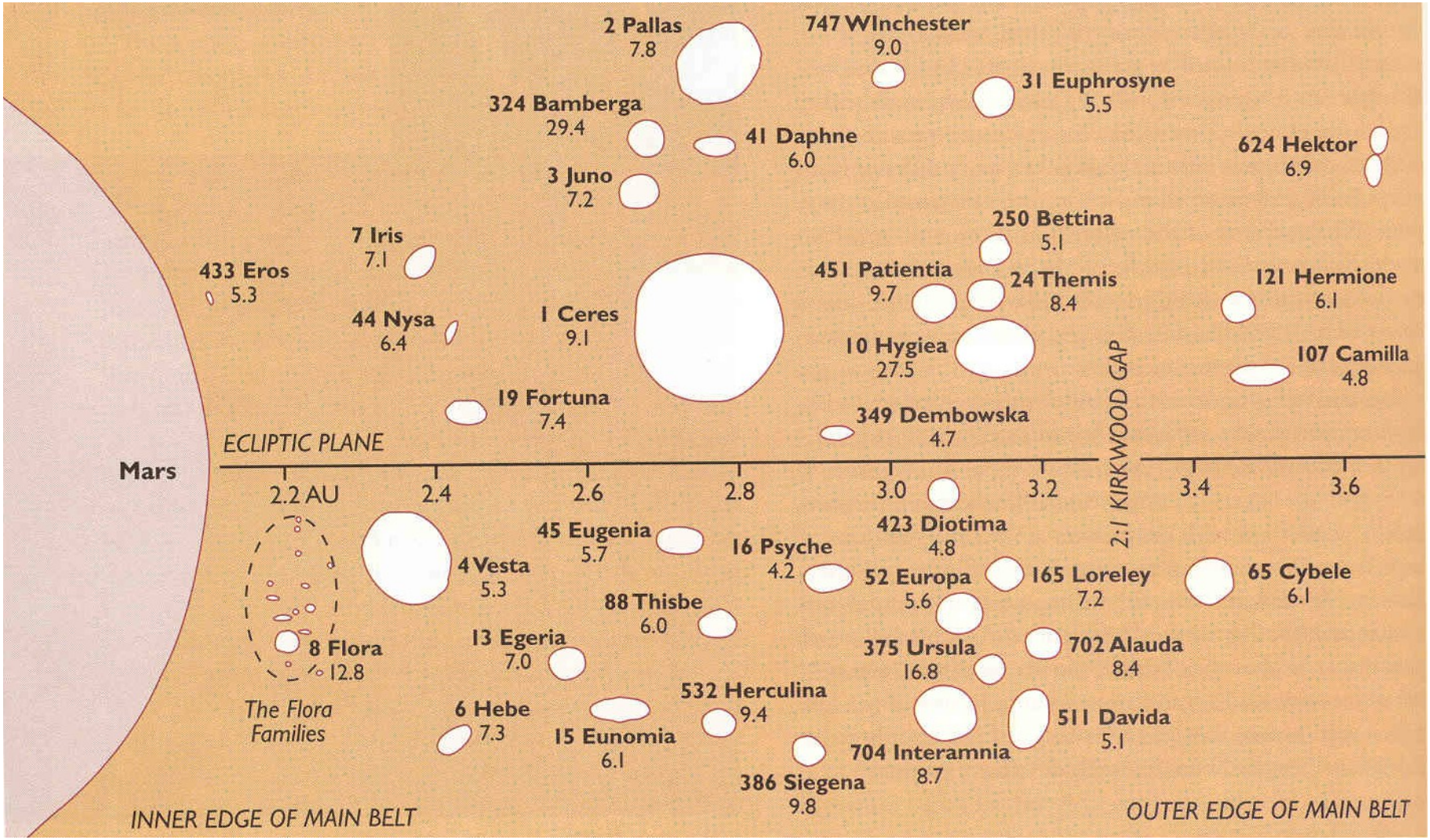


The New Solar System, Beatty et al.

- Most located between Mars and Jupiter
- Largest is Ceres
  - 1/3 diameter of moon
  - Most much smaller
- >8,000 known
- Total mass << Earth
- A few make it to earth
  - source of the meteorites
- Some located 60^o leading or following Jupiter
- Some cross the orbit of Earth

  [Apollo (a > 1) and Aten (a < 1)]

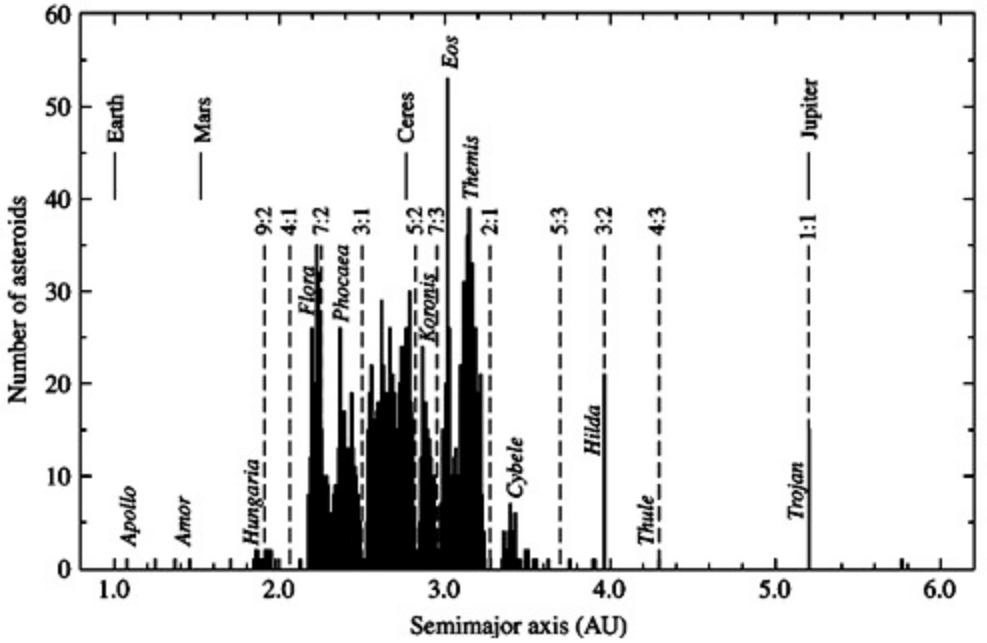
The larger asteroids

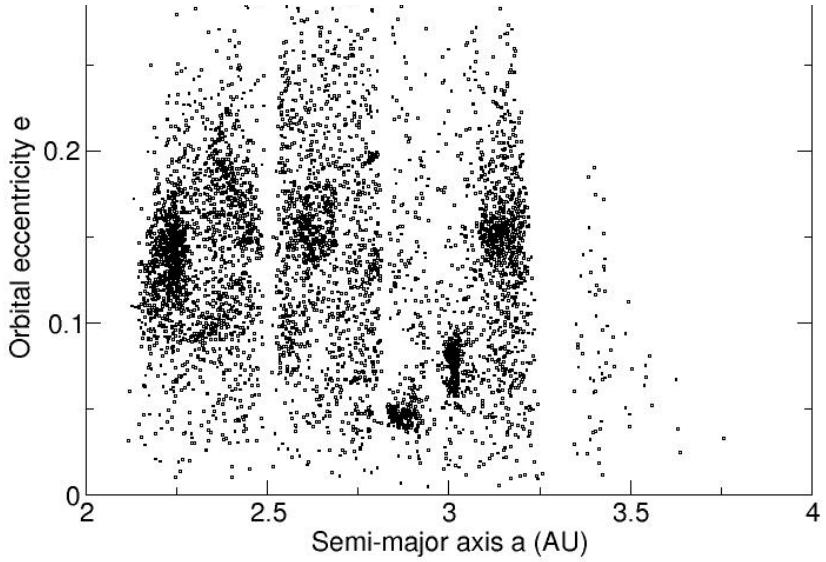


The New Solar System, Beatty et al.

Orbital Resonances with Jupiter

- Most asteroids are located between Mars and Jupiter
- Distribution of Periods is not Uniform
  - Peaks and gaps are present
  - Gaps occur are integer multiples of Jupiter's period
- Known as "Kirkwood Gaps"
- Asteroids are Periodically Perturbed Out of Resonance
- Thought to Be Source of Free Bodies
- Some meteorites Traced to Asteroid Belt





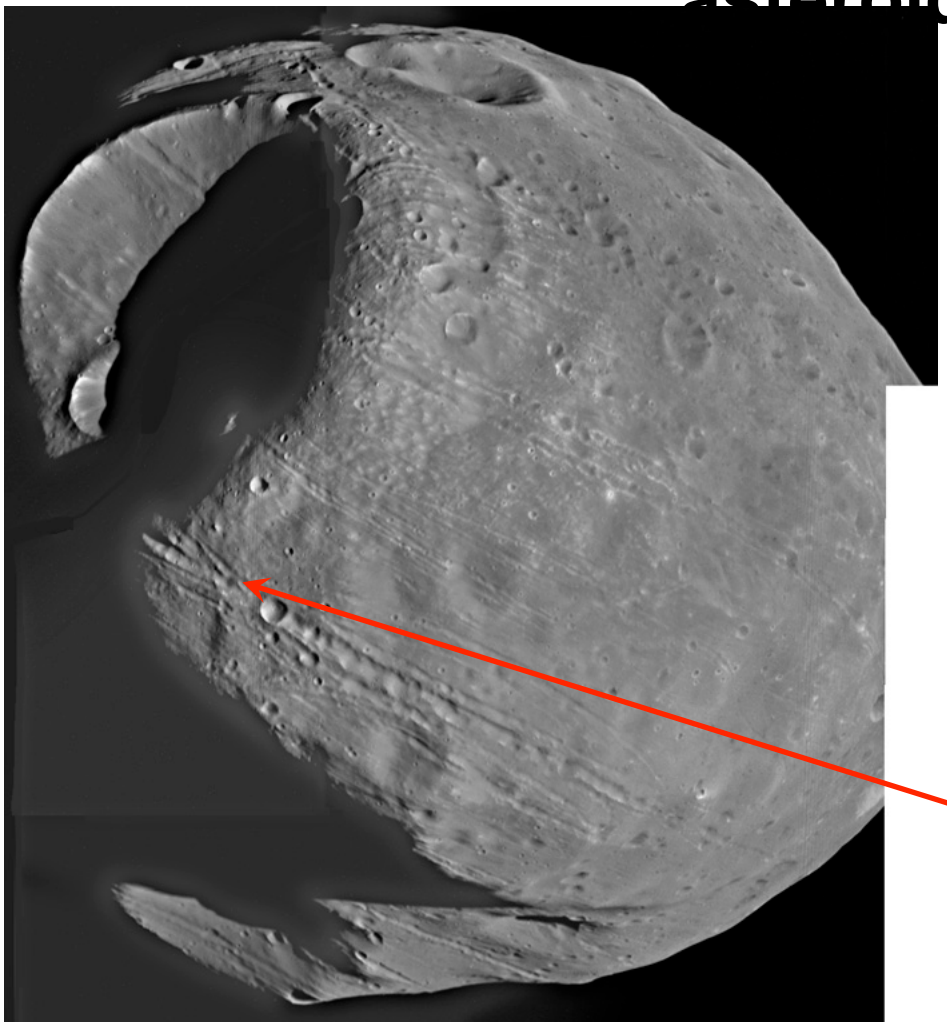
Are Asteroids Primitive?

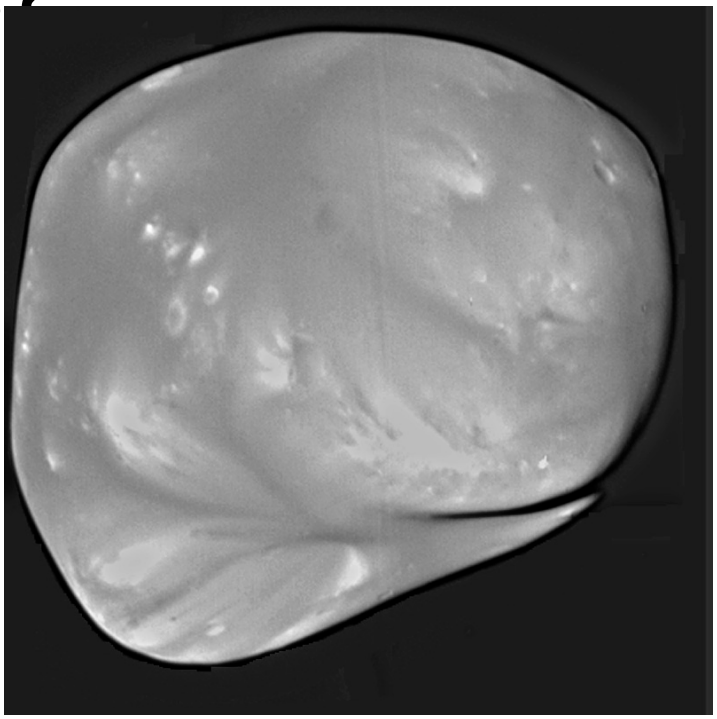
- Ida (56 km diam.) and its moon Dactyl (1.5 km diam.)
  - Colors have been "stretched" to show subtle differences
- Imaged by Galileo on its way out to Jupiter

- Presence of craters indicates great age
  - Absolute age requires knowledge of cratering rate – uncertain
  - Not spherical – gravity too weak to pull it into a sphere

Another Galileo Asteroid: Gaspra

Phobos & Deimos: Two "misplaced" asteroids?





Grooves seem related to the large crater called "Stickney"

- Phobos and Diemos are small (~25 km and ~15 km diam.) moons of Mars
- Look like captured asteroids rather than moons formed in place
- Are "C" class – i.e. dark "Carbonaceous" type "asteroids"

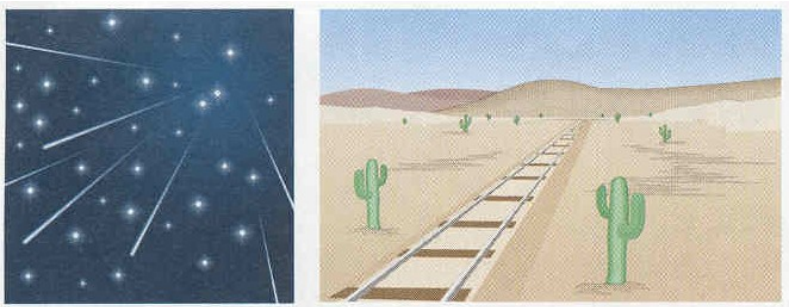
Meteorites

- Meteorites falling to Earth offer opportunity to collect asteroidal material
  - Interactions with Jupiter and/or each other can scatter them into Earth-crossing orbits
- Classification according to composition
  - S-type: silicates (stoney or rocky material)
  - C-type: carbonaceous (mixture of stoney and carbon material)
    - Located in outer belt, beyond 3 AU
    - Carbon compounds suggest cooler region of Solar Nebula
  - M-type: metallic
    - About 5% of total
    - Originating from core of differentiated massive body
  - Rare classes include objects which originated from the Moon and Mars

Large Meteor over the Tetons (1972)

Aphelion distance 2.3 AU
Diameter 3 to 10 m
Seen at height of ~50 km – skipped out of atmosphere

Meteor Showers and Comets



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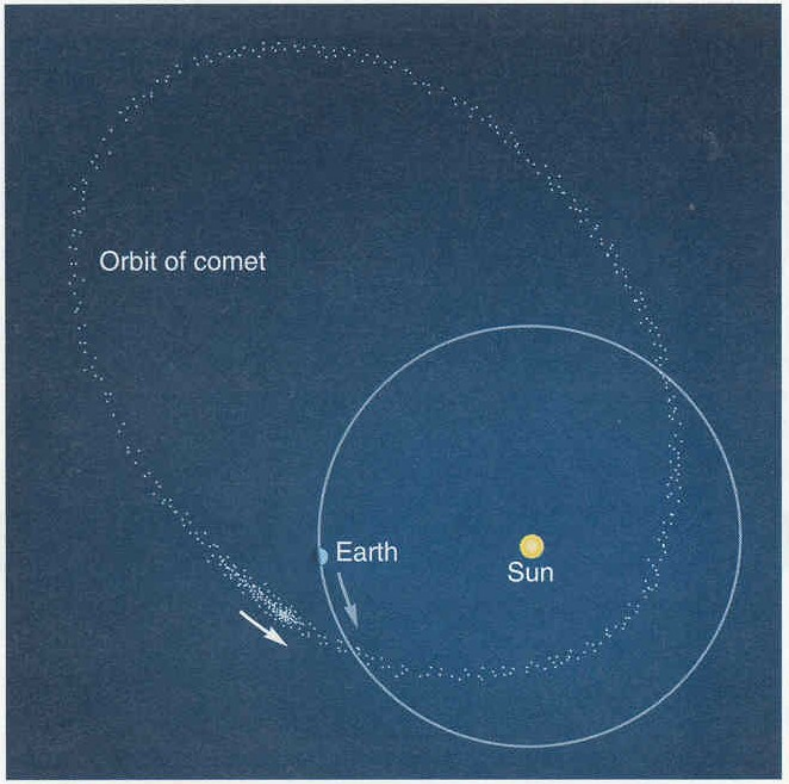


c

- Meteor showers caused by large amount of <u>small</u> debris spread out along comet orbits
- Almost none makes it to the ground – no meteor<u>ites</u>
- Occur each year as earth passes through orbit of comet
- Appears to come from "radiant point" in sky

- Leonids: Mid November

From our text Horizons, by Seeds

II. Comets

- **History**
  - Early Chinese astrological records report numerous comets
  - More recent, western records describe many as well
    - Edmund Halley recognized that one was periodic with a period of 76 years (Halley's comet)
- **Physical Nature**
  - Icy body surrounded by cloud of evaporating material
    - Nucleus: solid icy body abut 10 km in diameter
    - Head: cloud of H_2O gas immediately surrounding the nucleus
    - Tail: solar wind blows back material away from Sun
      - Ion tail: ionized gas streaming rapidly away from Sun
      - Dusty tail: more massive dust tail that partially streams back along the comet's trajectory
  - Nucleus features jets of escaping gas
    - Alteration of comet's orbit
    - Ejected dust source of interplanetary dust

Comets: Hale-Bopp in April 1997

Comet structure

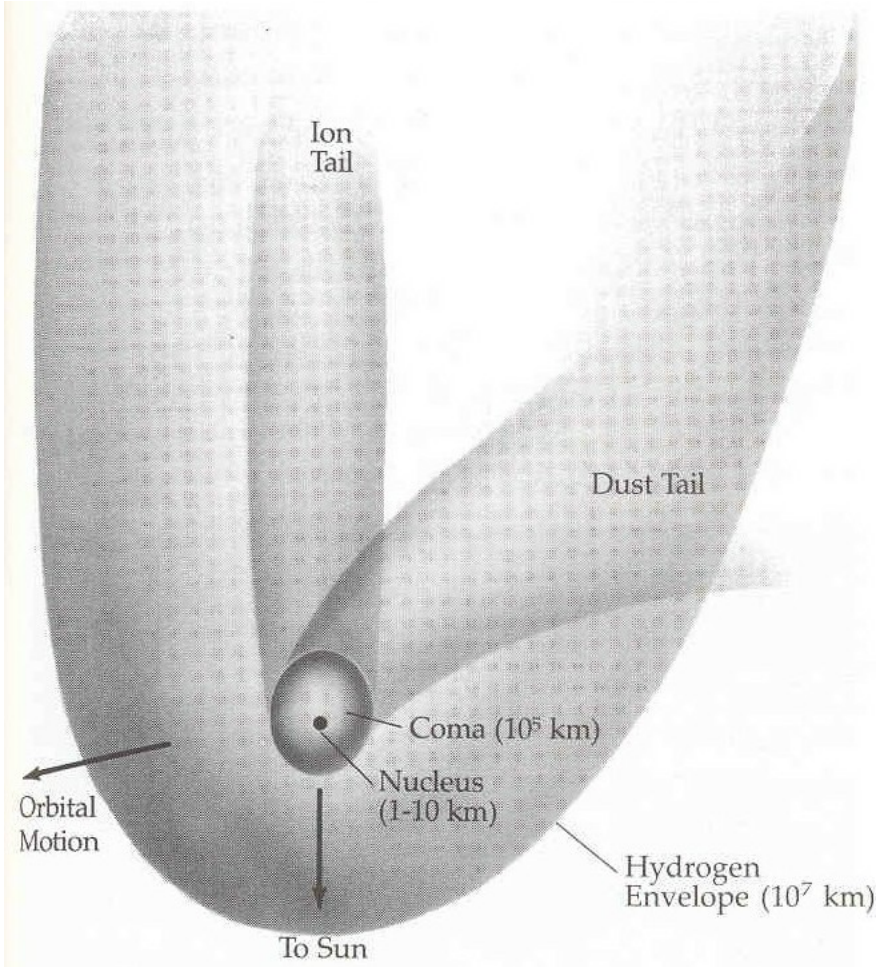
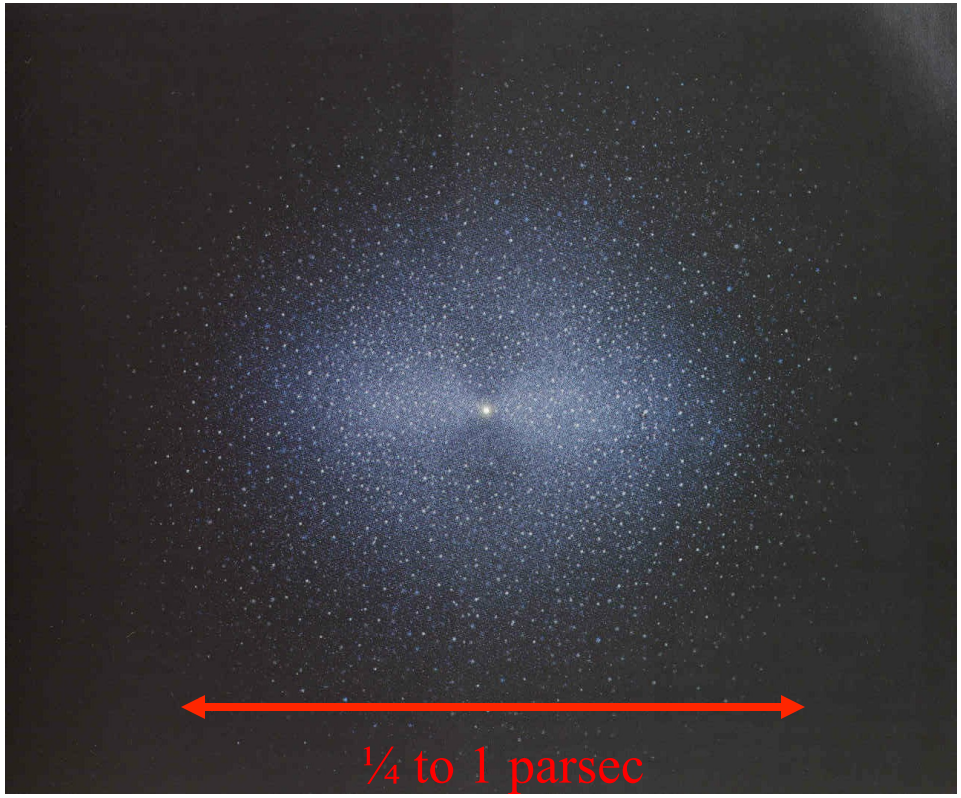


Figure 7–19 Schematic view of the main parts of a comet. Note that the comet is much larger than visible optically, but it originates from a very small nucleus.

- Gas sublimates from nucleus
- Dense coma surrounds nucleus
- Ion tail is ionized gas points directly away from sun
  - shows emission spectrum
  - ions swept up in solar wind
- Dust tail curves slightly outward from orbit
  - shows reflected sunlight
  - solar radiation pressure gently pushes dust out of orbit

Where do comets come from?

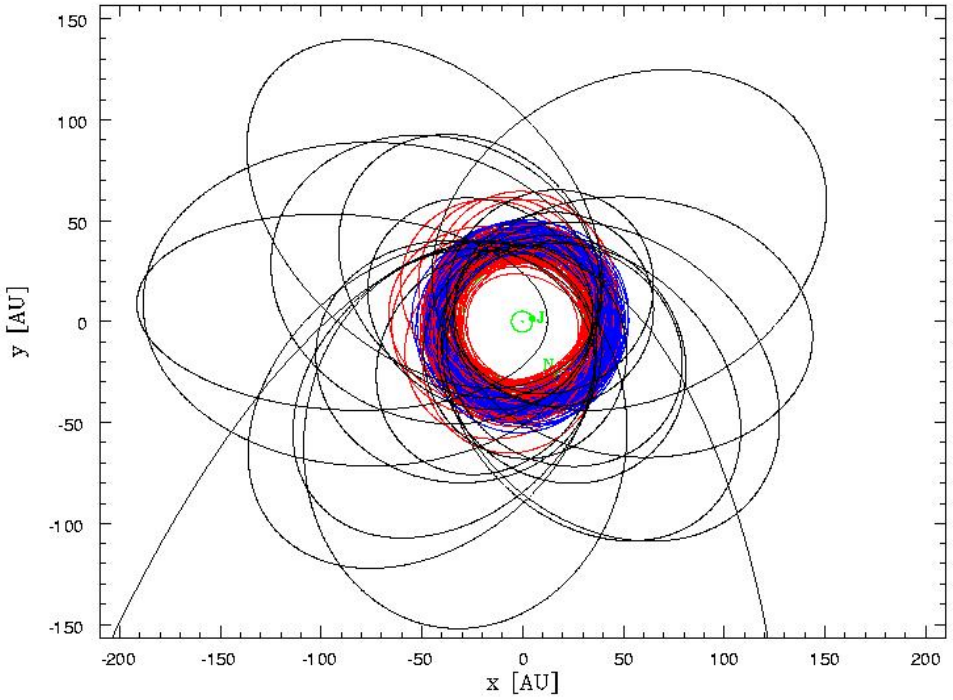
Long period comets: The Oort Cloud



The New Solar System, Beatty et al.

- Most (original) orbits have aphelions of >1000 AU
- Need ~6 trillion comets out there to produce number seen in here
- Total mass of 38 M_{Earth}
- Passing stars deflect comets in from the cloud

Where do the Jupiter family comets come from?: The recently discovered Kuiper Belt



- Material beyond Neptune never ejected into the Oort cloud
- Pluto and Charon the biggest members – now also Quarar, Sedna
- Very hard to detect because very faint
  - far from the sun so little illumination
  - comets not active at that distance
  - Hubble and new large telescopes have recently detected ~100

Importance of Asteroids & Comets

- Evidence of solar nebula
- Source of H_2O and CO_2 for earth
- Impacts continue
  - Impacts on Earth
    - Extinction of the dinosaurs
  - SL-9 impact on Jupiter

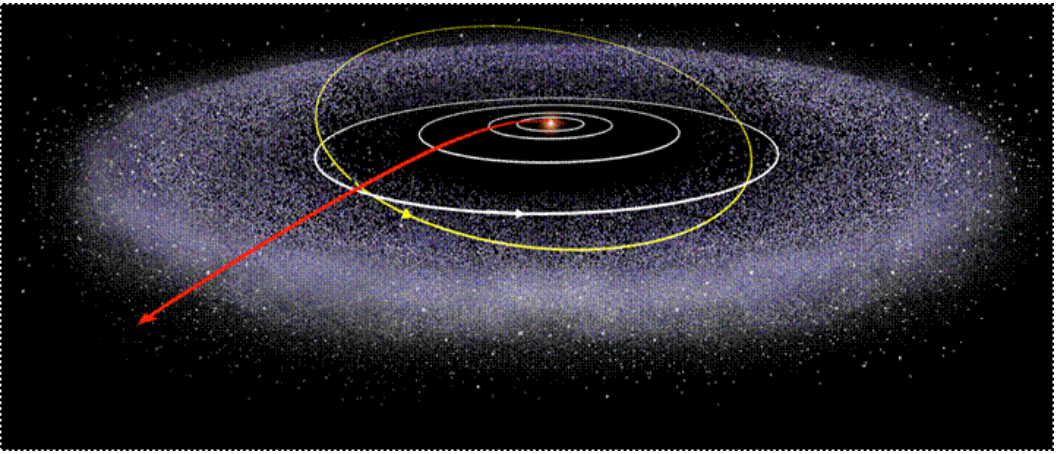
Chapter 11 cont.: Pluto and the Kuiper Belt

- **Exploration:**
  - Discovered by Tombaugh (1938) while looking for source of small, marginal perturbations in Neptune's motion. Mass and density known though eclipses with its moon Charon.
  - No longer considered a planet, Pluto is one of the largest members of the Kuiper Belt
  - New Horizons spacecraft will reach Pluto in 2015
- **Physical Properties:**
  - Mass: 0002 of Earth's
  - Diameter: 2,390 km (nearly 1/3 Earth's)
  - Avg. Density: ~ 2.0 gm/cc (mostly ice)
  - Rotation: siderial period of 6.4 days (tidally locked with Charon)
- **Interior**
  - Composition: a rocky core with mostly H_2O icy mantle and crust
  - Some NH_3 and CH_4 ice must be present given atmosphere.
  - Strong tidal field from Charon may create surface features (H_2O flows ?)
- **Atmospheric Features**
  - Thin atmosphere of N_2, CH_4, and CO.
  - Nothing else known
- **Origin**
  - One of the largest members of Kuiper belt
  - May have originated near Neptune and been ejected.

Largest known trans-Neptunian objects (TNOs)

Kuiper Belt & Oort Cloud

- **Our surveys have reveals a family of comets associated with the Kuiper Belt of larger, Pluto-like, objects.**



The Kuiper belt is flattened and is about 200 AU across but appears to merge with the more spherical Oort cloud on larger scales.